Historical phonology should be conducted with a basis in phonetics

*An argument for the use of Articulatory Phonology in diachronic phonology with an example analysis of Icelandic preaspiration**

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Abstract

In this thesis, I address the issue of framework suitability in historical phonology. I demonstrate that Articulatory Phonology, a theory of phonological representation, can be fruitfully combined with Optimality Theory, currently the most widespread theory of phonological processes, to describe sound change. I argue that this combination is suited for explaining sound change because it is firmly grounded in the physical movements of the mouth — meaning that only those sound changes which are natural can occur. As an example of this approach, I analyze the development of Icelandic preaspirated stops from Old Norse unvoiced geminates as an example of constraint promotion and interaction, and find that just a few, wholly natural constraint rankings are necessary to produce the typologically rare subsystem that can be observed in the Icelandic oral stops.

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1 Introduction

Traditionally, the study of historical phonology has been done by stating sound changes as informal or semi-formal rules, such as "schwa becomes a mid-close unrounded back vowel after a uvular fricative" or ə > ɤ / χ,ʁ __. However, this rule-based framework, among the first innovations of the field, has fallen out of usage in most synchronic phonology. And for good reason: despite their descriptive potential, not only do rules not offer much explanatory depth or power, but their formulation also allows the construction of implausible, unattested sound changes — e.g., ʃ > ħ / __l.

In this thesis, in order to create a framework purposefully suited for explaining sound change, I develop a new method of looking at historical change through the combination of Articulatory Phonology (AP; Browman and Goldstein 1986, 1992) and Optimality Theory (OT; Prince and Smolensky 1993/2004), offering an analysis of the Icelandic oral stops as a proof of concept.

I begin, in §2, by giving a short discussion of the phonological inventory of Icelandic,[1] as it relates to the phonological inventory of Old Norse (ON),[2] with emphasis on the oral stops. I also give an description of the ON realizations of geminate and singleton oral stops and the Icelandic realizations of their descendants. Regretfully, this thesis does not have the space to deal with the vowel shifts that occurred in the same time span.

In §3, I explain some of the particulars of AP, as it is not a theory in general usage, as well as certain assumptions that I make about how AP functions and the rationale behind those assumptions. In addition, I briefly explore the notion of contrast and its relation to the topic at hand. I do not go into a detailed explanation of OT, as I assume some amount of familiarity with the theory.

I finish in §4 by using a combination of AP and OT to analyze the development of the Icelandic oral stop subsystem, finding that, although preaspiration is generally considered a rare phenomenon, its occurrence in Icelandic oral stops can be found to arise from ON oral stops in a wholly natural manner. It is my intent that this result serve as a demonstration of the explanatory value of my approach.

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[1]In the literature, contemporary work done on Icelandic mostly refers to it as Icelandic or Modern Icelandic. In this thesis, I will use exclusively Icelandic.

[2]It should be noted that some texts make a distinction between Old Norse and Old Icelandic, with Old Icelandic being the period of time when the language had phonemic nasal vowels. This distinction is unimportant to this thesis.

2 Icelandic

2.1 Background

Icelandic is a West Scandinavian language of the North Germanic branch of the Indo-European family. It is spoken by about 310,000 people, mostly in Iceland, with small enclaves of speakers in Denmark and Canada (Lewis et al. 2015). Despite its relatively small number of speakers, Icelandic has been greatly studied for its syntax; it has been argued to be the only language with true quirky subjects (Faarlund 2001): grammatical subjects that are assigned case by their verbs instead of by an abstract tense head (Chomsky 1995). Icelandic has been somewhat studied for its phonology, but the literature is not extensive: linguists have been interested in only a few aspects of its synchronic phonology, predominantly the occurrence of preaspiration.

The cultural literature of Icelandic is vast, stretching back over 1000 years, although many works were only written down in the 11th–13th centuries (Gordon 1927). These works mainly consist of the *sögur* (singular *saga*; stories mostly about Viking history, common Icelanders, mythology, and saints) and of the *eddur* (singular *edda*; two large collections of poems and prose). These texts are important for a variety of cultural and historical reasons but also serve as an incredible source of linguistic information.

Two quirks of history have left us with enough information to ensure that modern linguistics is well-informed of the historical development of the language. First among these is the wealth of literature available to us, which has been carefully added to and well-preserved. The reasons for this general abundance is unclear, although theories abound: the folk wisdom is that, because the winters were too cold to do anything during, everyone learned to read and add to the sögur (Dagmar Steinbergsdóttir, p.c.); contrary to popular thought, historians have argued that a project of literature preservation existed as a result of aristocratic competition for prestige (Sigurðsson 1995, Eriksen and Sigurðsson 2015).

The second, and extremely vital, resource is the *First Grammatical Treatise* (FGT). Written some time between 1125 and 1175 by an unknown author referred to as the First Grammarian, the FGT is a recommendation on how to standardize Icelandic orthography. This recommendation is accompanied by an extraordinarily thorough phonemic analysis of Old Norse, conducted with methodology strikingly similar to that of modern linguistics. From this strong starting point in the Old Norse of the mid-12th century, we can rather easily and accurately use textual evidence to trace the history of sound changes in Icelandic.

2.2 Changes in consonants from ON to Icelandic

From the FGT, we know that the ON oral stop subsystem was originally contrastive in voicing (Gordon 1927), as can be seen in Table 1. The view that ON had a voicing distinction instead of some other distinction is widely found in the literature, although there is some small disagreement about the exact phonetic realization of singleton, word-medial oral stops. Nonetheless, it is agreed upon that the “voiced” and “voiceless” geminate oral stops were respectively voiced and unvoiced and that the “voiced” and “voiceless” singleton oral stops were respectively voiced (although potentially fricated) and unaspirated (Helgason 2002). Generally, Icelandic geminates are treated as a sequence of two identical phonemes.

	lab.	cor.	dor.	glot.
nasals	m	n		
stops	p b	t d	k g	
fricatives	f	θ, s		h
liquids		l, r		

Table 1: The Consonant System of Old Norse (based on Haugen 1950, Faarlund 2002)

Accounts of Icelandic, among them Árnason 2011 and Þráisson 1978, all agree that the distinction is now one of aspiration, as seen in Table 2.

	lab.	den.	pal.	vel.	glot.
nasals	m	n			
stops	p^h p	t^h t		k^h k	
fricatives	f v	θ, s			h
approximants		l, r	j		

Table 2: The Consonant System of Icelandic (based on Árnason 2011)

The change from a voicing distinction to an aspiration distinction can be seen as parallel to the fortis-lenis distinction found in many Germanic languages. Where Proto-Germanic had a voicing distinction, many descendants have changed that distinction into a complicated series of allophonic realizations (König and van der Auwera 2002, Harbert 2007); this has made it more convenient in many cases to refer to systemic contrasts in the stops by more featurally-agnostic terms, as no one specific feature accounts for phonemic contrasts in all positions, cf. English /t/ and /d/, which differ in aspiration word- and stressed-syllable-initially, but in voicing in most word-medial positions, and in the length of the preceding vowel word-finally. That said, the amount of allophony in Icelandic is limited, which allows the use of more precise terminology.

Numerous other changes occurred to the consonants between ON and Icelandic. Icelandic has between 16 and 21 consonant phonemes, depending on the analysis. The tables above reflect a minimal analysis of Icelandic, wherein the palatal oral stops [c cʰ] are analyzed as /kj/ and /kʰj/ and the voiceless sonorants [n̥ l̥ r̥] are analyzed as /hn hl hr/. A /w/ emerged, and then merged with [v], creating the phoneme /v/, and a /j/ appeared from certain vowel sequences and vowel shifts.[3]

Until recently, the aspirated oral stops were aspirated in all environments. In 2016, this consistency in the aspiration is only true for northern Icelandic (Sigmundsson 2002). Speakers of the southern variety, which includes those living in the capital Reykjavík, now exhibit word-positional allophony in their realizations of the oral stops:

(1) /tʰau̯l-a/ 'deceitfulness-GEN.PL' > [tʰau̯ːla]
/au̯tʰa/ 'krill.NOM.SG' > [au̯ːta]
/lau̯tʰ/ 'death.NOM.SG' > [lau̯ːt]

(2) /ɛlt-ɪ/ 'cook-1SG.PRES' > [ɛltɪ]
/ɛl-tʰɪ/ 'cook-1SG.PAST' > [ɛl̥tɪ]

Icelandic has a complex and rich inflectional system, in which nouns are declined for case and number, as shown in the examples in (1).

As seen in (1), /tʰ/ is realized as [t] when not word-initial, although there are exceptions and complications. For example, (2) shows that an underlying /tʰ/ triggers anticipatory devoicing of sonorant consonants. Thus, /tʰ/ has not completely merged with /t/ in all non-initial positions. Note that there is phonetic vowel lengthening, the specifics of which are rather complicated, although the complications are not apparent in these examples.[4] This information is only included in the interests of heading off any potential confusions, as southern Icelandic is more studied. This thesis focuses on northern Icelandic, which has [tʰ] in all positions for /tʰ/ and lacks anticipatory sonorant devoicing.

In contrast to the singleton oral stops, the allophonic variation in the geminate oral stops is the same in all varieties of Icelandic.

Recall that Icelandic has a complex inflectional system; its adjectives are declined for case, number, gender, and presence of a determiner on the associated noun. One of the major adjective declension patterns is -ur/-∅/-t for indefinite nominative singular nouns, with the choice of suffix depending on gender. As shown in Table 3, it is apparent

[3]Icelandic has 13 vowel phonemes, and the structure of the vowel system has also changed significantly from ON to Icelandic. Unfortunately, although the vowel shifts are very interesting, this thesis does not have the room to give them appropriate consideration.

[4]See Árnason 1980 for some discussion on this, although most texts on Icelandic take a stab at the problem.

	/-ʏr/ ‘MASC.NOM.SING’	/-∅/ ‘FEM.NOM.SING’	/-tʰ/ ‘NEUT.NOM.SING’
/kʰvitʰ/ ‘white’	kʰviːtʰʏr̥	kʰviːtʰ	kʰviht
/plei̯kʰ/ ‘pink’	plei̯ːkʰʏr̥	plei̯ːkʰ	plei̯ktʰ

Table 3: Adjective declensions

that a /tʰtʰ/ sequence is realized as [ht]. In addition, words which are known to have been originally realized with geminate unvoiced stops are now realized with preaspirated stops, cf. *ekki* ‘not’ ON [ekki] > Icelandic [ɛhcɪ]. Thus, there is both synchronic evidence in morphological alternation as well as historical evidence that underlyingly aspirated geminate stops are realized as preaspirated stops.

It is important to note, however, that while preaspiration is the term traditionally used to describe this phenomenon, recent work such as Árnason 2011 has argued that the burst of air preceding the stop is best described as a devoiced vowel — that is, an /h/ — rather just aspiration.[5] This is the account that I will use, in lieu of older analyses.[6] A summary of the changes that are discussed is given in (3).

(3) $$\begin{bmatrix} \text{g} & \text{gg} \\ \text{k} & \text{kk} \end{bmatrix} > \begin{bmatrix} \text{k} & \text{kk} \\ \text{k}^{\text{h}} & \text{hk} \end{bmatrix}$$

2.3 The timing of changes from ON to Icelandic

Gordon (1927) writes that the change in the oral stop subsystem was a push chain starting in the velars — this is reasonable, as velar stops are more prone to devoicing than fronter stops and there exists a trend of increased difficulty of articulation of voiced stops as the place of articulation moves closer to the vocal cords (Ohala 1983, Westbury and Keating 1986, Napoli et al. 2014). Since the difficulty of maintaining voicing increases as duration increases, the length of a geminate makes voiced geminates prone to devoicing. This would be, as with singleton stops, subject to the same trend of increased, positional difficulty of articulation. Further, given that voiced geminate stops are generally perceptually

[5]See Malone 1923, 1952, Einarsson 1945, Haugen 1958, Þráisson 1978 for older accounts of Icelandic preaspiration.

[6]For a detailed, synchronic Government Phonology analysis of preaspiration, see Árnason 2011, which concludes that to label the Icelandic oral stop system as having an aspiration contrast is misleading, and there exists a deeper issue of how the glottis must be open in certain positions. See also Þráisson 1978 for a rule-based analysis that mostly deals with another aspect of preaspiration, the change of /Tʰl Tʰn/ to [hTl hTn], but also touches on the issue of geminate preaspiration.

weak (cf. Kawahara's (2006) discussion of Japanese geminates), it is doubly reasonable that the voiced geminate velar stops also devoiced.

Although I cannot definitely establish the order of the changes, it is likely that /g/ devoiced alongside or just after the devoicing of /gg/, thus forcing /kk/ and /k/ to gain new realizations. For simplicity, I will analyze the changes as if they had occurred simultaneously. Thus, I treat the entire issue at hand as two simultaneous chain shifts: in the geminates, /gg/>[kk], /kk/>[hk]; in the singletons, /g/>[k], /k/>[k^h].

After, or perhaps simultaneous with the devoicing of the velar oral stops, the exact same phenomenon occurred in both the alveolar and bilabial oral stops, with the same type of outcome: previously unvoiced singleton stops aspirated, and previously unvoiced geminate stops preaspirated. Since these push chains are exactly the same but for their places of articulation, there is no need to go through each of them one by one. Thus, this thesis will focus on the velars, as it is certain that the velar oral stop series was the first to change, with the understanding that the analysis changes only minutely for the alveolar and the bilabial oral stop series.

3 Theory

3.1 Articulatory Phonology

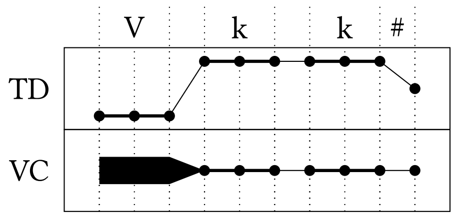
In this section, I give a brief overview of AP, discussing its basic premises, how it is depicted, and certain theoretical assumptions that have been made in its implementation. I then briefly discuss what previous work has been done in combining AP with OT in the field of synchronic phonology.

3.1.1 Gestural scores

As developed by Browman and Goldstein (1986, 1990, 1992), AP is a formal theory of representational phonology wherein *gestures*, movements of the articulators of the mouth, and their relative positions in time, are construed as the most basic units of phonological analysis. These gestures are depicted on diagrams known as *gestural scores*.

In their original formulation of AP, Browman and Goldstein (1992) give a way to depict scores consisting mostly of boxes; in this thesis, I eschew that suggestion in favor of a system of more visually understandable graphs which incorporate both the theoretical considerations that have been added to the theory as well as the assumptions I make. A sample score is given in (4).

(4)



The main area of a score is a large box with smaller, abutting boxes within it. Outside of this large box are labels which serve to guide the reader. This is similar to a musical score in concept, with each smaller box analogous to a different instrument.

Some transcription — here, in IPA — is given above the main box in what I will call the *transcript row*. See §3.1.2 for more discussion of transcription placement. To the left of the large box are abbreviations that label the adjacent *sub-box* as representing a particular *vocal tract variable* — here with TD representing the tongue dorsum and VC representing the vocal cords. These are parameters that specify the spatial goals of the speech act.

These vocal tract variables come in two types: *locations* and *degrees*. These variables are originally referred to in the literature as *constriction locations* and *constriction degrees*. However, I believe that the use of the word "constriction" is misleading, as not all locations, e.g., the vocal cords, should be thought of as producing constrictions. Therefore, I omit "constriction" except when correct. The information contained within the sub-box is a representation of the (constriction) degree.

The x-axis is a representation of time, with the beginning of the analyzed utterance at the extreme left and the end at the extreme right. Small vertical sections, which I will call *t-units* are marked in the sub-boxes by vertical dotted lines — every pair of vertical lines marks a t-unit, and each t-unit is an important unit of time as considered by the current analysis. The question of what length of time each t-unit actually represents is left purposefully vague; some may be much shorter than others, and t-units may so short as to approach having no real length. The extension of the dotted line into the transcript row is an indicator of which t-units are part of a speech sound, with the lines which enter the transcript row indicating the ends of sounds. In (4), the [V] is two t-units long. Following the [V] is a single transition t-unit to a [k]; the [k] is also two t-units long.

For articulators that create constrictions, such as the tongue dorsum, the y-axis of that particular sub-box should be understood as the location of the articulator relative to the top of the mouth. The gesture line is dark between any t-units that are part of a speech sound, and light during any transition t-units between sounds. Dots are placed within the box at the beginnings and endings of gestures, as well as midway between those points. The vertical location of the gesture line and the rationale for dot placement will be discussed in §3.1.2. If desired, the degree of a gesture can be labeled for clarity on the score, but such a practice is not necessary in this thesis.

For articulators, such as the vocal cords, which do not have positions so much as states, the various states are shown in a visually appropriate manner. Here, voicing is depicted as a thick section and lack of voicing is depicted as a regular gesture line. The transition between these states is shown as a triangle, to iconically represent gradual devoicing.

It is important to note that scores only need to include the gestures necessary to the analysis: although the tongue tip is assuredly doing something in (4), even if that something is resting, its position is irrelevant and is thus can be omitted.

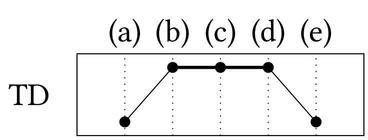
3.1.2 Assumptions of and additions to the theory

When looking at phonology and not phonetics, constriction gestures in AP are said to have five contrastive degrees: [closed], [critical], [mid], [narrow], and [wide].[7] These distinctions correspond to the general categories of sounds: [closed] refers to stops, [critical] to fricatives, and [mid], [narrow], and [wide] to approximants and vowels, with all approximants being [mid] and vowels being any of the three, depending on vowel height.

We can see that translation between featural representations of phonology and AP is only difficult for abstract features, such as [±liquid] (although see Proctor (2009) for a discussion of the unifying phonetic features of liquids); nasality can be depicted with a velic opening, rounding by showing the degree of lip spreading.

The original formalization of AP does not refer to any unit larger than a single gesture. However, any working theory of phonological processes must acknowledge the existence of timing units and syllables, so even though Browman and Goldstein do not explicitly include such things in their scores, they can be assumed to exist regardless. A *segment* is a unit corresponding to all of the gestures that combine to create a perceived sound. Going back to (4), [V] is a segment, as are each of the [k]s. In between is a transition t-unit which can been seen as part of both the [V] segment and the first [k] segment, having certain characteristics of both.

(5)



[7]In phonetics, and thus, actual production, there are theoretically infinite realizable degrees, although the idea is that there would remain just five *contrastive* degrees.

Gafos (2002) argues that gestures should be thought of as having five *gestural landmarks*, as shown in (5). This can be seen as the formalization of observations made in Cho (1998) and Browman and Goldstein (1988). In the middle of the gesture is the *perceptual plateau*, which is what listeners identify as a particular sound. This plateau includes three landmarks, the target (b), the center (c), and the release (d). On both sides of the plateau are transitions: (a) is the onset, the beginning of the transition from no specified gesture to the target and (e) is the offset, the corresponding end of the transition from the release to either the unspecified or to a following target. Following his lead, here, the perceptual plateau (b–d) is depicted with three dots, and the transitions are understood to be in the space between gestures. Returning to (4), it should be understood that the transition t-unit of [V] to the first [k] is not only the (d–e) of [V], but also the (a–b) of [k].

It is unclear if it is necessary to think of geminates and long vowels as single segments or multiple, adjacent, identical segments. For the purposes of this thesis, the distinction is irrelevant, but it is not hard to imagine a case where that might not be so. Here, following observations made in the literature about Icelandic, and for simplicity, I classify geminates as two segments, with the understanding that the fundamental analysis would sill hold if they are classified as a single segment.

One of the exciting innovations of AP is its explanation of the Autosegmental Phonology (Goldsmith 1976) assertion that vowels continue through the perceptually audible part of a vowel into adjacent consonants (Clements 1976/1980, McCarthy 1981). As in Autosegmental Phonology, sequential vowels in an utterance are always adjacent; in some meaningful manner, they meet in the middle of the consonants that separate them. However, AP finds that this does not mean that every feature of the vowel is preserved but that just *some* portion is. The perception of a vowel is merely occluded by the presence of a consonant.

This can be seen as an explanation of vowel harmony, wherein rounding harmony is characterized by the preservation of the position of the lip position through intervening consonants, and place harmony as a preservation of certain aspects of the tongue body. Research done by Gafos (2002) indicates that this is also why consonant harmony such as that found in Chumash is apparently restricted to coronal consonants, as the tongue tip can preserve a shape gesture through intervening noncoronal consonants, but the tongue body is unable to do so.

3.1.3 AP and OT

The earliest work combining AP and OT is Cho's (1998) work on Korean palatalization. Since then, other efforts have been made to merge AP and OT, all in the realm of synchronic phonology. Notable texts include Bradley's (2002, 2007) work on Norwegian derived retroflexes, Bradley's (2014) work on Spanish intrusive schwas, Hall's (2003) dissertation on vowel intrusion, and Gafos's (1999) dissertation on the applicability of AP to vowel and consonant harmony. Much of this work has made reference to the articulatory landmarks of Gafos (2002), giving rise to a family of constraints called Coord constraints. It is unfortunate that it would take too much space to properly explain the constraints that have already been proposed; however, since I do not actually make use of them, it would have been redundant to do so anyway.[8]

No one has, to my knowledge, used AP with OT to analyze historical data. However, precedents from both theories should still hold true in a combination of the two. In regular OT, historical change can be modeled as a reranking of constraints (as in Cho 1995).[9] Hence, AP/OT should be the same. As with other uses of OT, an analysis must determine which constraints have been promoted and which demoted. This is the base assumption of the analysis done in §4.2.

3.2 Clarifications to AP

There are certain elements of AP, and thus of AP/OT, which I believe are ambiguous and need to be addressed. These are the identification of segments, the construction of markedness constraints, the definition of a segment, and the nature of gestural change.

3.2.1 The identification of segments

As stated in §3.1.1, segments must be labeled with a transcription, identifying that segment as being a particular sound. Due to the roots of AP in phonetics, the adaptation of AP to phonological questions raises the issue of determining which gestures are part of a sound. For example, some languages are said to have register systems, because while they have contrastive tone, each tone is also associated with a particular type of phonation (see Huffman 1976 for an account of this in some Mon-Khmer languages). For phenomena such as register systems, it is difficult to know which gestures are crucial to a segment and which are not.

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[8]For a clear paper that provides examples of many constraints, look at Bradley 2007, although I have some misgivings about his analysis.

[9]However, see Reiss 2003 for an interesting alternative.

A solution is that segments should be labeled by referring to the canonical representation of a sound, if such a canonical representation exists. An /n/ is canonically an alveolar nasal stop. Thus, in AP, /n/ has a constriction of [closed] at the tongue tip and a lowered velum, and a segment with those characteristics should be labeled as an /n/. If it is unclear what a canonical representation should be, then all of the gestures as they actually occur in the language should be described, and the closest label should be assigned, with the acknowledgment that the label is somewhat arbitrary.

3.2.2 The construction of markedness constraints

Related to the issue of segment identification is the question of how OT constraints should be formulated in AP/OT. Constraints such as *PL/Palatal (Prince and Smolensky 1993/2004) must be reformulated to make reference to the correct units while still preserving the original intent of the constraint.

(6) *PalatalObstruent (*PalObs)
There is no constriction at the palate of any degree [critical] or higher. Mark one violation for each t-unit with a palatal constriction degree of [critical] or [closed].

I give (6) as an example of how I believe constraints such as *PL/Palatal should be reformulated. Most importantly, such a constraint must not rule out vowels such as [i], as that would not be the intention; in AP, a restriction based on constriction degree is easy to define and this aspect of the theory should be fully utilized. Appropriately, constraints should be named such that their meaning is transparent, hence *PalObs instead something such as *Palatal.

The reason that this constraint counts t-units that instead of gestures or segments in (6) is simple: there might be languages without even phonetic palatal consonants. These languages would tend to not have even transitory constrictions at the palate and so should never have even a single transitory t-unit with such a constriction.[10] If a language has some palatalization of a consonant but no palatal consonants overall, then an appropriate constraint, *PalatalSegment, can be formulated, which would be of the form in (7)

(7) *PalatalSegment (*PalSeg)
No segment has a constriction at the palate of any degree [critical] or higher for its

[10] Sequences such as [kt] might conceivably have some amount of palatal constriction in the transition between the [k] and [t] segments, although I am unsure if there truly is any palatal constriction. From a purely personal perspective, when I say words such as *actor* [æktɚ], my tongue briefly forms a u-shape in the transition, if you were to imagine seeing my tongue in profile. *My* tongue does not move, so to speak, the constriction smoothly from my velum to my alveolar ridge.

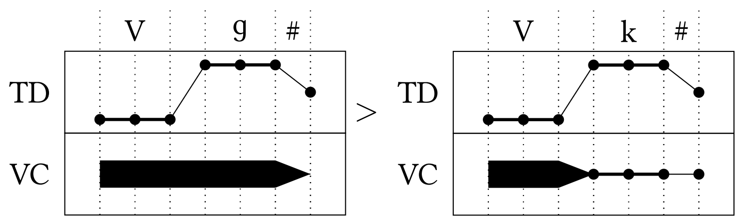
complete duration. Mark one violation for each segment encompassed by a palatal constriction gesture of [critical] or [closed].

A constraint such as *PalSeg would allow segments to have minimal or partial overlap with palatal constriction gestures, allowing for palatalization without allowing wholly palatal consonants.

3.2.3 The nature of gestural change

A common question in synchronic phonology is how to best treat phenomena when multiple ways are applicable. Although I will not go into the specifics here, when the nasal substitution found in the Austronesian languages is considered, it becomes important to decide if /ŋp/>[m] is a merger caused by low-ranking Uniformity (Pater 1999, 2001) or an assimilation followed by a deletion. This question is, I think, more prominent in applications of AP, because AP deals with so many more units that can be changed.

(8)



(8) is given to show an example of this problem. The difference between [Vg] and [Vk] is that [Vg] has a voiced VC gesture during the stop and [Vk] has a voiceless VC gesture. Such a change would necessarily be a change in voicing in a featural analysis, but this is not true in AP. AP must decide if, in moving from [Vg] to [Vk], it was that the voicing gesture was deleted and then a gesture of voicelessness was inserted, or it was that the voicing gesture became a voicelessness gesture.

There appears to be no evidence for one approach over the other. As this particular deletion-insertion question does not arise when dealing with featural representations, I want to show that, even when a more complicated assumption is made, that the analysis still works. Therefore in my first analysis, I assume that voicing gestures must be deleted and then reinserted to effect a voicing change. This is the bulk of the analysis done in §4. For completeness's sake, in §4.3, I will assume that gestures can be directly changed and conduct an analysis under that schema as well.

3.3 Contrast

The importance of the notion of contrast to the structure of language dates back as early as Trubetzkoy and de Saussure. The fundamental idea of contrast is that contrasts can be drawn between different linguistic objects; these contrasts serve to keep words[11] distinct from each other. For example, there is a contrast between English *cap* and *cat*, and on the phonological level, the two are distinguishable from each other because of a contrast in the last segment, a difference of the presence of the phoneme /p/ versus /t/.

Contrast is also the difference between syntagmatic and paradigmatic approaches to linguistics. With the advent of the idea of phonemes, sounds gained the ability to be studied in systems and paradigms instead of just in individual utterances. As languages change, contrast can be introduced or neutralized in various environments, ultimately resulting in both the creation and merger of phonemes. These are changes in the complete system, not only on the level of a word or prosodic unit. This, therefore, is paradigmatic linguistics, and the topic of this thesis.

That phoneme mergers occur is something of a question for linguistics, considering the frequency of *chain shifts*: when multiple sounds of a particular subsystem shift such that a new subsystem is formed; an example of a chain shift is the English Great Vowel Shift (Jespersen 1949). Chain shifts can be conceptualized of as *push chains* and *pull chains*; canonically, push chains are when a particular phoneme impinges on the perceptual space of another phoneme, causing that second phoneme to move and impinge on another, etc.; pull chains are when a phoneme moves and frees up perceptual space, with a second phoneme then occupying that space and freeing up space somewhere else, etc. While pull chains pose no problems for linguistics, push chains such as the Great Vowel Shift do: it is complicated to formally prevent all of the involved phonemes from simply merging into each other in a push chain.

This issue has been formally approached in a number of theories including Dispersion Theory (DT; Flemming 1995, 2004) and Contrast Preservation Theory (CPT; Łubowicz 2003), which formalize the necessity of maintaining systemic contrasts. These theories do not only target phoneme mergers, but also address the process of keeping individual words contrastive with each other.

The methods that DT and CPT go about preventing mergers is different and there exist criticisms of each.[12] To represent this property of language in a non-denominational manner, I use in this thesis a constraint from Padgett (2003), *Merge, as a cover constraint for any sort of merger-preventing constraint.

[11] Or morphemes, or roots, or abstract entries in the lexicon.

[12] For example, Vaux and Samuels (2005) argue that DT is based on flawed generalizations about vowel systems that do not hold up to phonetic analysis. Sanders (2003) shows that DT better accounts for the vagaries of Polish opacity than CPT.

(9) *MERGE

No word of the output has multiple correspondents in the input. Mark one violation for each instance where two inputs map onto the same output. (Padgett 2003)

*MERGE is demonstrated in Figure 1, which shows that if a system comes from a previous system where two separate members are now represented by a single member, violations are incurred. In an effort to clarify, I show the system with subscripts: any given phoneme is shown with the same subscript from input to output, despite any change in realization. In this example, previous [gg_2] and [kk_4] merge into [$kk_{2,4}$]. This leaves the system with less members than it started with, and incurs a violation. In this thesis, I treat deletion of a phoneme as a merger with ∅.

$$\begin{bmatrix} g_1 & gg_2 \\ k_3 & kk_4 \end{bmatrix} > \begin{bmatrix} g_1 & \\ k_3 & kk_{2,4} \end{bmatrix}$$

	g_1 gg_2 k_3 kk_4	*MERGE
a. ☞	g_1 gg_2 k_3 kk_4	
b.	g_1 k_3 $kk_{2,4}$	*!

Figure 1: *MERGE violations

4 Analysis

In this section, I discuss how constraint interaction results in the Icelandic oral stop system. Because scores do not fit well into tableaux, I show how scores incur violations outside of tableaux to demonstrate the logic behind the violations and only give the transcription in the tableaux. I also do not show scores which incur the same violations as previously shown scores. For a complete, simultaneous representation of the scores in this section, please see Appendix A.

4.1 Candidate sets

I determined in §2.3 that although it is possible to make a very educated guess at the order of the changes in the velar oral stops, that guess would still be just a guess. Thus, it is necessary to consider the entire system at once — however, in order to properly consider the effects of constraints on a system, all possible outcomes must be analyzed simultaneously. This raises a few problems.

(10) $\begin{bmatrix} \text{g} & \text{gg} \\ \text{k} & \text{kk} \end{bmatrix} > \begin{bmatrix} \text{k} & \text{kk} \\ \text{k}^{\text{h}} & \text{hk} \end{bmatrix}$

Reproduced from §2.2 is (10), which shows the changes in the velar oral stop subsystem from ON to Icelandic. If we consider only those elements which are attested, either in ON or Icelandic, the only outcomes we need to evaluate are those with constituent members of the set

(11) $\{\text{gg}, \text{g}, \text{kk}, \text{k}, \text{hk}, \text{k}^{\text{h}}\}$

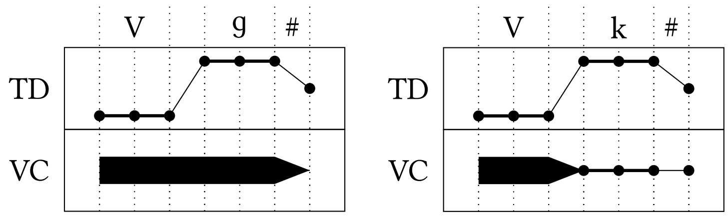
This gives us over a thousand outcomes fitting that criteria, which is far too many to evaluate meaningfully or to even fit on a page. However, recalling that I suggested in §3.1.3 that historical change in AP/OT should be modeled as promotion or demotion of constraints, we can rule out many of the candidate possibilities by promoting certain constraints to sufficiently high positions. We will cull the candidate outcomes to just those that do not violate any undominated constraints.

In this case, a pre-established constraint can be applied: *Merge. It is paramount to my analysis that no mergers occur, since we know that, historically, no mergers did occur. By accounting for the promotion of *Merge to an undominated position, I disallow repeating outputs from the input list, greatly reducing the number of relevant candidates to just a few hundred. Although still a ludicrous situation, this is a significant improvement over the previous.

As discussed in §3.2.2, new constraints should both be specific and follow precedent. Ideally, at least for historical analysis, they should also represent truths about general linguistic tendencies; the fount of those tendencies is irrelevant. Given the tendency for velar obstruents to devoice and the double tendency for geminate velar obstruents to devoice, I propose the constraint *VVO, which I give in (12).

(12) *VoicedVelarObstruent (*VVO)
There is no voiced constriction at the velum of any degree [critical] or higher. Mark one violation for each t-unit that contains any amount of voicing as well as a tongue dorsum gesture with a constriction degree of [critical] or [closed].

*VVO is demonstrated in Figure 2, which shows that [Vg] violates *VVO three times, for both the onset transition t-unit of [g], and for the two t-units of the perceptual plateau of [g]. Note that the onset transition t-unit of [g] has voicing during a TD gesture with a constriction degree of at least [critical]! Since violations of *VVO are incurred on the basis of t-units, even part of a t-unit is sufficient for a violation.



Vg	*VVO
a. Vg	∗∗∗
b. Vk	∗

Figure 2: *VVO violations

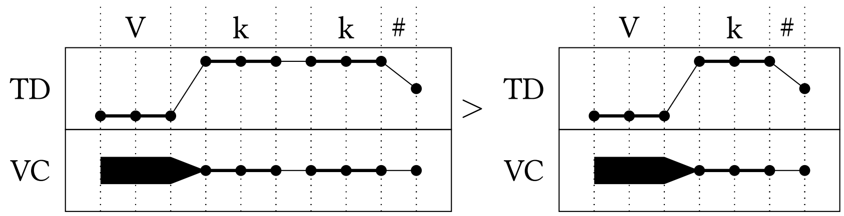
In comparison, [Vk] violates *VVO once, for the onset transition t-unit. Note here that I have not counted the offset transition t-unit in the violations — this is because it is unclear if that transition t-unit should be ever considered when marking violations. *VVO should be seen as a combination of many familiar OT constraints such as *g, *gg, *ɣ, into a single constraint reformulated to fit the requirements of AP. Justification for this constraint's existence would be redundant at this point, given previous discussion here and in §2.3.

It is to be understood that this constraint is the only difference between the shift in the velar oral stop series and the alveolar and bilabial series. The impetus behind the chain shift in the alveolar oral stops would be a constraint *VoicedAlveolarObstruent (*VAO), formulated analogously to *VVO. Similarly, the impetus behind the chain shift in the bilabial oral stops would be a constraint *VoicedBilabialObstruent (*VBO).

When we look at the historical data, we know that *VVO was promoted over some constraint, although still remaining under *Merge. We can therefore remove /g/ and /gg/ from the set of possible outputs, leaving us with 24 candidate outcomes. This is almost manageable, but we should also consider a commonly used constraint, Max, which I have redefined for AP in (13).

(13) Max
Do not delete any segments. Mark one violation for each segment present in an input not present in an output. (based on Prince and Smolensky 1993/2004)

Although it is important to reformulate Max for AP, the overall principle of prohibiting deletion is the same. By promoting Max to a high position, /gg/ is forced to become [kk] or [hk], as all other possible outputs involve segment deletion. Obviously, this does the same for /kk/. This is shown in Figure 3. With the addition of Max, our candidate outcomes are narrowed down to just four.



Vkk			*VVO	Max
a.	☞	Vkk	*	
b.		Vk	*	*!

Figure 3: Max violations

It is implied by the data that Max was highly ranked overall because ON had length contrasts in the vowels as well as the consonants, and the number of timing slots, or segments, has been preserved in the consonants to the present day. Since the vowels maintained a length contrast until after the change in the stops had finished, it is reasonable to conclude that any demotion of Max from its high-ranking position did not occur until then.[13]

Dep, also reformulated for AP analogously to Max, is also highly ranked. although its existence is unimportant to the analysis at hand, as adding segments does not make pre-existing segments violate *VVO any less. Since absolutely no segments were lost or added, it may be more accurate to create a constraint that preserves the number of t-units, although I do not do this here.

(14)

gg g kk k			*Merge	*VVO	Max
a.	☞	kk k hk k^h			
b.	☞	kk k^h hk k			
c.		k kk hk k^h			*!
d.		k^h k hk k			*!
e.	☞	hk k kk k^h			
f.	☞	hk k^h kk k			

(14) is a small portion of an unwieldily large tableau showing the combined effects of *Merge, *VVO and Max. (14a,b,e,f) harmonically bound all other outcomes, as they have

[13]See Schulte 2002, Sandøy 2002 for details.

no violations for any of the three constraints and all other candidates have at least one violation. Because of *VVO, all outcomes with any [gg] or [g] are harmonically bounded by (14a,b,e,f), as they intrinsically violate *VVO. All outcomes with any mapping of /gg/ or /kk/ to any singleton realization are harmonically bounded by (14a,b,e,f) because of Max. Therefore, (14a,b,e,f) are the only outcomes that need to be considered, because they are the only outcomes that contain no mergers, have no voiced velar obstruents, and maintain the number of segments from input to output. With just these four outputs to consider, I can begin to determine the necessary constraint rankings.

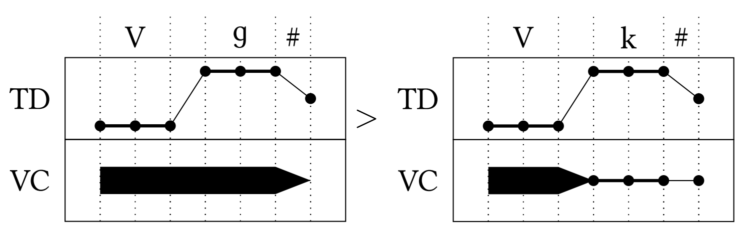
4.2 New constraints

In this section, I discuss constraints which make explicit reference to elements of AP. This section will be broken into two parts, one which deals with the geminates and one with the singletons. After establishing the rankings which produce the correct singletons and geminates, I will combine the two rankings and discuss the overall analysis of the oral stop system as a whole.

4.2.1 The geminates: /gg/>[kk]

First, I consider the different violations incurred by /gg/ as it becomes [kk] or [hk]: currently, it incurs none. Therefore, I assert the existence of Max-G:

(15) Max-Gesture (Max-G)
Do not delete any gestures from segments. Mark one violation for each gesture present in an input not present in an output segment.

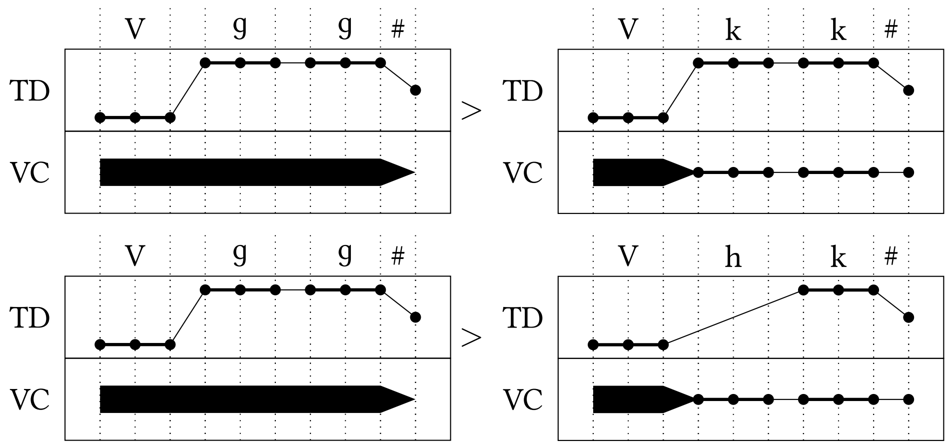


Vg		Max-G
a. ☞	Vg	
b.	Vk	*

Figure 4: Max-G violations

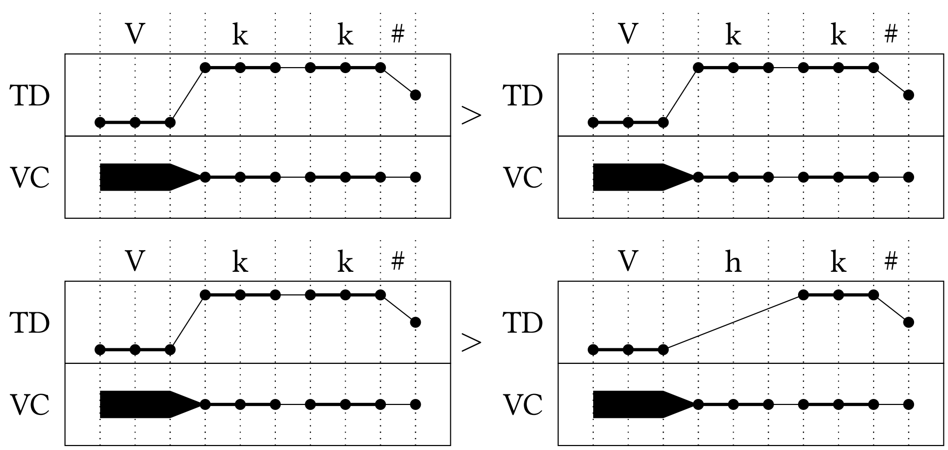
Max-G is demonstrated in Figure 4, which shows that /Vg/ > [Vk] violates Max-G just once, for the voicing gesture present in the /g/ segment which is not present in the [k] segment. It is clear that a constraint such as (15) must exist as a natural extension of Max; where Max is concerned with not decreasing the number of segments, Max-G is concerned with not decreasing the number of gestures. Indeed, in come circumstances, Max functions as a more permissive version of Max-G, as the deletion of all gestures from a segment results in a segment deletion. Yet, when we consider its effects, we see that its existence as a low-ranking constraint produces an inconclusive output.

(16)



Vgg	Max-G
a. ☞ Vkk	**
b. Vhk	**!*

(17)



Vkk	Max-G
a. ☞ Vkk	
b. Vhk	*!

Because /Vgg/ > [Vkk], [Vhk] will always incur at least two violations of Max-G from the deletion of the voicing gestures, /Vgg/ will always prefer the candidate which /Vkk/ prefers. This is very similar to harmonic bounding: since /Vkk/ > [Vkk], [Vhk] will incur no violations of Max-G from the deletion of voicing gestures and /Vgg/ > [Vkk], [Vhk] will always incur two violations from the deletion of voicing gestures, they will always prefer the same outcome. The relevant scores are shown in (16) and (17). That both /Vgg/ and /Vkk/ have the same realization is disallowed by *Merge, which gives us the overall tableau in (18).

(18)

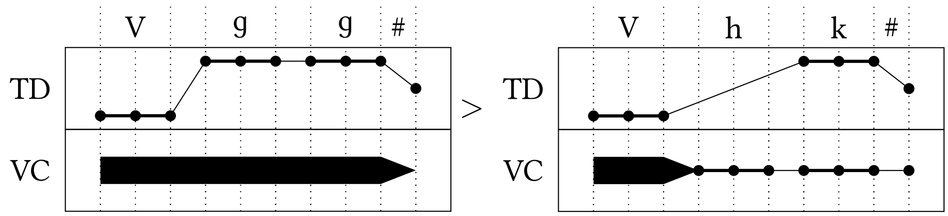
(gg, kk)			*Merge	Max-G
a.	☞	(kk, hk)		∗∗∗
b.	☞	(hk, kk)		∗∗∗

Because /gg/ > [kk], [hk] always incurs two violations for the deletion of the voicing gestures, and /gg/, /kk/ > [hk] always incurs one violation for the deletion of the dorsal constriction gesture, both outcomes are equally bad, and have three total violations. Max-G is clearly not important as a constraint by itself; its importance is in its self-conjoined version, Max^2-G. Conjunction constraints have been part of OT since Prince and Smolensky 1993/2004 as a way of being more selective about violations, the rationale being that local multiple constraint violations are categorically worse than the same violations in a nonlocal context — the same violations all in one word/morpheme/segment is worse than those violations spread out over a few words/morphemes/segments. Self-conjunction is a special type of conjunction formally developed by Alderete (1997) where violations are only counted if the same constraint is locally violated multiple times. A particularly useful application of conjoined constraints is to prevent outputs from changing too radically from their inputs in a specific feature while still allowing some amount of change in that feature. This is obviously relevant in chain shifts, where inputs must be prevented from skipping the line and jumping to the end of the chain, so to speak.

(19) Max^2-Gesture (Max^2-G)

Do not delete two or more gestures. Mark one violation for each gesture present in an input not present in an output, as long as two or more gestures are not present.

Max^2-G is demonstrated in Figure 5, which shows that /Vgg/ > [Vhk] violates Max^2-G twice, because there are three violations of Max-G: two for the voicing gestures present



Vgg		Max^2-G	Max-G
a.	Vgg		
b. ☞	Vhk	*!*	* * *

Figure 5: Max^2-G violations

in the /gg/ segments which are not present in the [hk] segments, and one for the dorsal constriction that is deleted to obtain the [h].

Recall that the chain shift in the geminates is /gg/>[kk], /kk/>[hk]. It is important to stop /gg/ from going directly to [hk]. Thus I suggest a constraint that incurs violations when multiple changes occur at once. Hence, if we add Max^2-G to the tableau, we obtain (20).

(20)

(gg, kk)		*Merge	Max^2-G	Max-G
a. ☞	(kk, hk)		*	* * *
b.	(hk, kk)		**!	* * *

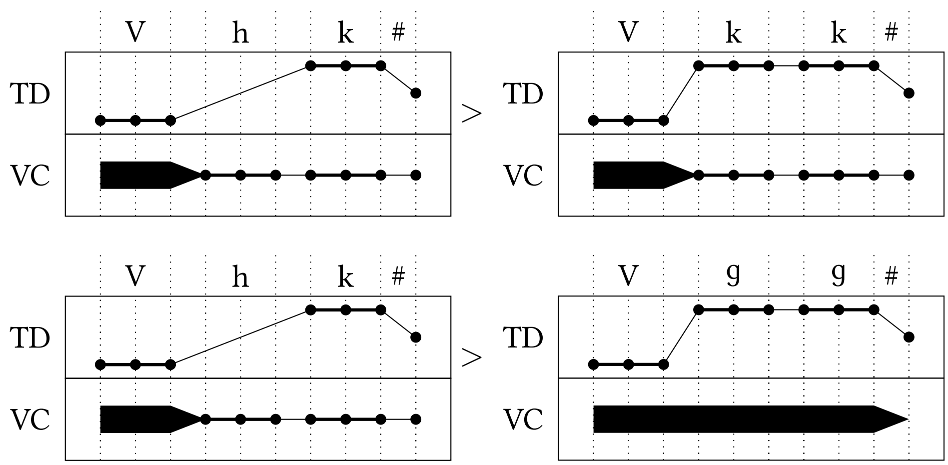
Thus, Max^2-G is crucial to describing ON > Icelandic. Note that we know Max^2-G outranks Max-G because constraint conjunctions must always outrank their component constraints (Prince and Smolensky 1993/2004). However, that particular ranking is unimportant; its is enough for Max^2-G to be ranked under *Merge for us to get Icelandic from ON. Since the shift in the subsystem was necessarily precipitated by the promotion of *VVO with already high-ranking *Merge and Max, it is reasonable that Max^2-G is ranked below all of those, allowing the right results to naturally fall out from the constraints.

Another way of formulating Max^2-G is by limiting its scope to a segment instead of a number of segments. For this analysis, this would have the effect of decreasing the number of Max^2-G violations in /Vgg/ > [Vhk] to one, as only the first /g/ segment would incur a violation for deletion of both the dorsal constriction gesture and the voicing gesture. However, this would also have the effect of decreasing the number of Max^2-G violations in /Vgg/ > [Vkk] to zero, as I treat the geminates as two segments. Therefore, a change in the formulation of MAX^2-G would still produce the correct results.

4.2.2 *The singletons: /k/>[kʰ]*

Here, I begin by asserting the existence of DEP-GESTURE:

(21) DEP-GESTURE (DEP-G)
Do not add any gestures. Mark one violation for each gesture present in an input not present in an output.



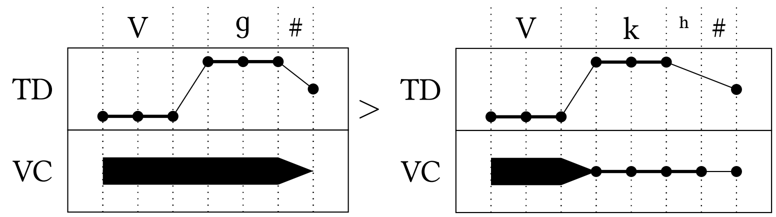
Vhk	DEP-G
a. ☞ Vkk	*
b. Vgg	**!*

Figure 6: DEP-G violations

DEP-G is demonstrated in Figure 6, which shows that /Vhk/ > [Vkk] violates DEP-G once, for the addition of the dorsal constriction gesture. /Vhk/ > [Vgg] violates DEP-G three times, once for the addition of the dorsal constriction gesture and twice for the addition of two voicing gestures.

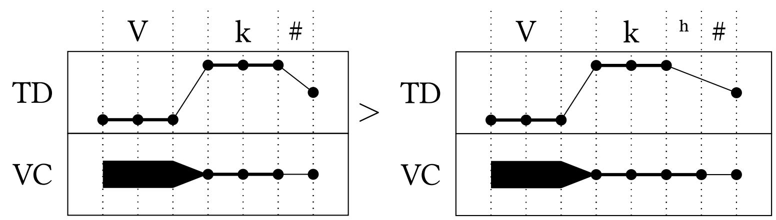
A constraint such as DEP-G exists as a natural extension of DEP; where DEP is concerned with not increasing the number of segments, DEP-G is concerned with not increasing the number of gestures. Yet, when we consider its effects, we see that its existence as a low-ranking constraint produces an inconclusive output.

(22)



Vg			Dep-G
a.	☞	Vk	*
b.	☞	Vk^h	*

(23)



Vk			Dep-G
a.	☞	Vk	
b.	☞	Vk^h	

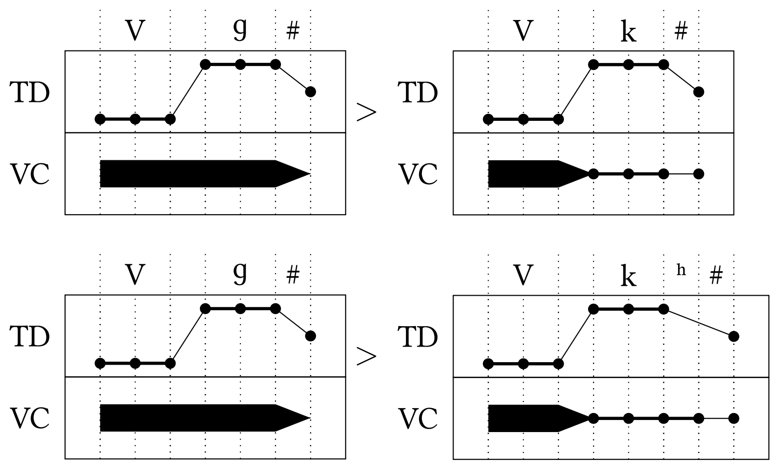
Recall that in §3.2.3, I established that a change in voicing is a deletion followed by an addition. I suggest that this is not true for the lengthening of gestures, as there is already a pre-existing gesture with the correct degree present. Because /Vg/ > [Vk], [Vk^h] will always incur at least one violation of Dep-G from the addition of the voicelessness gesture, /Vg/ does not have a definite winner. Similarly, because /Vk/ > [Vk], [Vk^h] will always incur no violations of Dep-G, /Vk/ does not have a definite winner. The relevant scores shown in (22) and (23), show us that both /g/ and /k/ can become both [k] and [k^h]. This ambiguous outcome is disallowed by *Merge, which gives us the overall tableau in (24).

(24)

(g, k)			Dep-G
a.	☞	(k, k^h)	*
b.	☞	(k^h, k)	*

Because /g/ > [k], [k^h] always incurs one violation for the addition of a voicing gesture, and /k/ always incurs no violations, both outcomes are equally bad, and have one violation. Dep-G is clearly not important as a constraint by itself; its importance is in its extension Dep-LG.

(25) Dep-LongGesture (Dep-LG)
Do not add any long gestures. Mark one violation for each gesture longer than a segment present in an input not present in an output.



Vg	Dep-LG	Dep-G
a. ☞ Vk		*
b. Vk^h	*!	*

Figure 7: Dep-LG violations

DepL-G is demonstrated in Figure 7, which shows that /Vg/ > [Vk^h] violates Dep-LG once, for the addition of the long voicelessness gesture. /Vg/ > [Vk] does not violate Dep-LG, so [Vk] is the winner.

The formulation of Dep-LG is slightly unclear because, as noted in §3.1.2, the notion of a segment is slightly unclear. Here, I mean that adding gestures that are longer than the segments they "belong" to is a violation of Dep-LG, the example in Figure 7 showing that the extended voicelessness of [Vk^h] counts as a long segment because it extends past the [k]. I am implicitly making the assumption that aspiration is not its own segment, as that would be an [h], but is also not a transition. I am also assuming that changing the length of a pre-existing gesture does not require deletion and reinsertion.

From Figure 7, we see that if we add Dep-LG to our tableau, we obtain (26).

(26)

(g, k)	*Merge	Dep-LG	Dep-G
a. ☞ (k, k^h)			∗
b. (k^h, k)		∗!	∗

Thus, Dep-LG is crucial to describing ON > Icelandic. Although the ranking of Dep-LG with respect to Dep-G cannot be determined, its is enough for Dep-LG to be ranked under *Merge for us to get Icelandic from ON. It is also impossible to rank Dep-LG,Dep with respect to Max^2-G/S or Max-G, but I will show that it is unnecessary to have them strictly ranked with respect to each other. Again, since the shift in the subsystem was necessarily precipitated by the promotion of *VVO with a high-ranking *Merge and Max, it is reasonable that Dep-LG is ranked under all of those, allowing the right results to naturally fall out from the constraints.

4.2.3 The entire system

At this point, the only outcome not examined is (gg, g, kk, k) > (hk, k^h, kk, k). However, the violations incurred by the separate parts of this outcome have all been previously discussed, so I will not go over the rationale behind the violations that are incurred.

(27)

(gg, g, kk, k)	*Merge	Max^2-G	Dep-LG
a. ☞ (kk, k, hk, k^h)		∗	
b. (kk, k^h, hk, k)		∗	∗!
c. (hk, k, kk, k^h)		∗∗!	
d. (hk, k^h, kk, k)		∗∗!	∗!

Examining (27), we see that with high-ranking *Merge, *VVO and Max reducing the potential outcomes to four, the constraints Max^2-G/S and Dep-LG are sufficient to produce the attested Icelandic oral stop subsystem from that of ON. In fact, the winning, attested candidate harmonically bounds all of the other candidate outcomes. Max^2-L/G and Dep-LG are the only truly necessary constraints, and do not have to be ranked with respect to each other.

4.3 What if gestures can be directly changed?

In §3.2.3, I established that I would conduct my analysis under the assumption that gestures cannot change degree but must rather be deleted and then a gesture with the sought-after degree added. This has the effect of making a change in voicing violate both Max-G and Dep-G. This would also imply that affrication or spirantization might incur the same violations. If we instead work under the assumption that voicing gestures can be changed to voicelessness gestures instead of requiring deletion and then replacement, then an analysis with Max-G and Dep-G does not apply. Instead, we must consider Ident constraints, here Ident[Voice]-Gesture and Ident[Duration]-Gesture.

(28) Ident[Voice]-Gesture (Id[Voi]-G)
Do not change voicing gestures. Mark one violation for each voicing gesture in the output which has a different degree in the input. (based on McCarthy and Prince 1995)

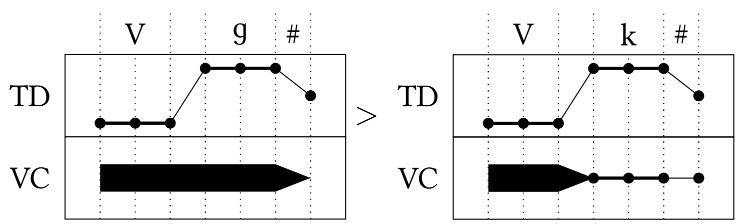


Figure 8: An Id[Voi]-G violation

Id[Voi]-G is demonstrated in Figure 8, which shows that /Vg/ > [Vk] violates Id[Voi]-G just once, for the voicing gesture present in the /g/ segment which is not present in the [k] segment. Id[Voi]-G is the reformulation of the associated Ident constraint first proposed in McCarthy and Prince 1995.

(29) Ident[Duration]-Gesture (Id[Dur]-G)
Do not change the duration of gestures. Mark one violation for each gesture in the output with a different length from the input. (based on McCarthy and Prince 1995)

Id[Dur]-G is demonstrated in Figure 9, which shows that /Vk/ > [Vk^h] violates Id[Dur]-G just once, for the change in the length of the voicelessness gesture present

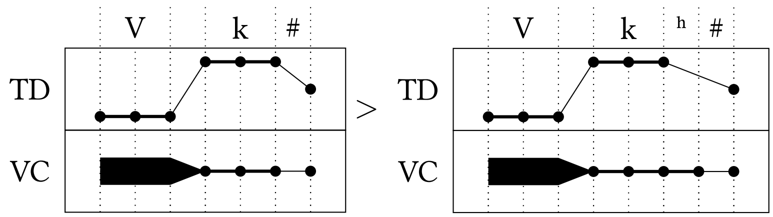


Figure 9: An ID[DUR]-G violation

in the /k/ segment which becomes the [kʰ] segment. Like ID[VOI]-G, ID[DUR]-G is simply the reformulation of the associated IDENT constraint first proposed in McCarthy and Prince 1995. Note that ID[DUR]-G is being implicitly violated in §4.2.2, although I do not bring the matter up because, as [kʰ] is attested from /k/, I assume that ID[DUR]-G is low-ranking, below both MAX^2-G and DEP-LG.

The result of high-ranking *MERGE is that any valid outcome must have exactly four elements, and [kk], [k], [hk], and [kʰ] must be represented once in all of those valid outcomes. Any input that results in [kʰ] must violate ID[DUR]-G, because of the lengthening of the vocal cord gesture associated with the input's stop. /gg/ and /g/ will always violate ID[VOI]-G three times in total, for the two voicing changes /gg/ must undergo and the one that /g/ must. Therefore, when evaluated as a system, all of the potential outcomes violate each constraint equally, giving us an inconclusive output.

Recall that the chain shift in the geminates is /g/>[k], /k/>[kʰ]. It is important to prevent /g/ from going directly to [kʰ]. Thus I suggest a constraint which incurs violations when two changes occur at once — here, a voicing change and a duration change. The solution, then, would be a conjunction of the two, ID[VOI&DUR]-G.

(30) IDENT[VOICE]&[DURATION]-GESTURE (ID[VOI&DUR]-G)
Do not change voicing gestures and the duration of gestures. Mark one violation for each voicing gesture in the output which has both a different degree as well as a different length in the input.

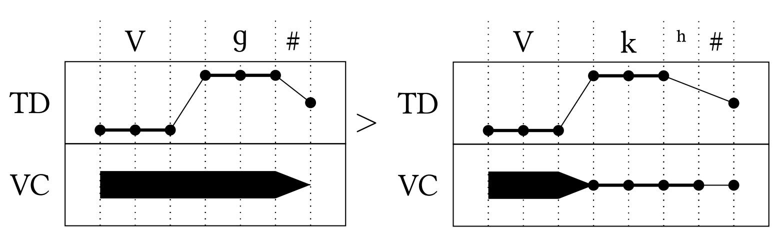


Figure 10: An ID[VOI&DUR]-G violation

Id[Voi&Dur]-G is demonstrated in Figure 10, which shows that /Vg/ > [Vk^h] violates Id[Voi&Dur]-G just once, for the vocal cord gesture of the /g/, which changes both in its degree and in its duration. From Figure 7, we see that if we add Id[Voi&Dur]-G to our tableau, we obtain (31).

(31)

	(gg, g, kk, k)	*Merge	Id[Voi&Dur]-G
a.	☞ (kk, k, hk, k^h)		
b.	(kk, k^h, hk, k)		$*$!
c.	☞ (hk, k, kk, k^h)		
d.	(hk, k^h, kk, k)		$*$!

With the addition of Id[Voi&Dur]-G, we see that outcomes where /g/ > [k^h] are harmonically bounded by outcomes where /g/ > [k]. This leaves two candidate outcomes to consider.

Recall that the chain shift in the geminates is /gg/>[kk], /kk/>[hk]. It is important to prevent /gg/ from going directly to [hk]. Thus we suggest a constraint that incurs violations when two changes occur at once — here, a voicing change and a gesture deletion. The solution, then, would be a conjunction of the two, Id[Voi]-G&Max-G.

(32) Ident[Voice]-Gesture&Max-Gesture (Id[Voi]-G&Max-G)
Do not change voicing gestures and delete a gesture from the same segment. Mark one violation for each gesture present in an input segment not present in an output segment, as long as the voicing of that gesture has also changed in degree.

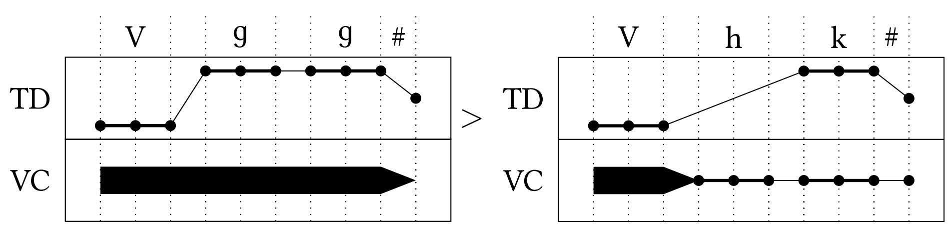


Figure 11: An Id[Voi]-G&Max-G violation

Id[Voi]-G&Max-G is demonstrated in Figure 11, which shows that /Vg/ > [Vhk] violates Id[Voi]-G&Max-G just once, for the first /g/ segment, because there is both a change in the voicing gesture as well as a deletion of the dorsal constriction gesture in the same segment. From Figure 11, we see that if we add Id[Voi]-G&Max-G to our tableau, we obtain (33).

(33)

(gg, g, kk, k)			*Merge	Id[Voi&Dur]-G	Id[Voi]-G&Max-G
a.	☞	(kk, k, hk, k^h)			
b.		(kk, k^h, hk, k)		∗!	
c.		(hk, k, kk, k^h)			∗!
d.		(hk, k^h, kk, k)		∗!	∗!

Examining (33), we see that with high-ranking *Merge, *VVO and Max reducing the potential outcomes to four, the constraints Id[Voi&Dur]-G and Id[Voi]-G&Max-G are sufficient to produce the attested Icelandic oral stop subsystem from that of ON. In fact, the winning, attested candidate again harmonically bounds all of the other possible outcomes. Id[Voi&Dur]-G and Id[Voi]-G&Max-G are the only truly necessary constraints, and do not have to be ranked with respect to each other.

Thus, we see that no matter the nature of voicing changes in AP/OT, the Icelandic oral stop subsystem can be obtained from that of ON with two constraints. If voicing changes are a deletion followed by an addition, then a constraint conjunction and a normal constraint must be used. If voicing changes are changes in identity, then two constraint conjunctions must be used.

4.4 Discussion

Overall, the use of a framework which incorporates phonetics has served to make clear the necessity of particular constraints. By using gestures and t-units as the fundamental units of analysis, it is extremely apparent what constraints might be violated. This allows us to immediately see which violations are permissible, and thus ranked lowly, and which violations are not, and thus ranked highly. This sort of comparison is best done when both inputs and outputs are known, as direct comparison is otherwise not possible. We can see that this method can be extremely useful when applied to historical data, as that is one of the few cases in phonology with explicitly realized inputs and outputs.

An issue with my analysis that I was unable to resolve is the lack of relationship between the constraints that I suggest are what produce the Icelandic oral stop subsystem. In my Max/Dep analysis, the geminate chain shift of /gg/>[kk], /kk/>[hk] is explained by the self-conjoined constraint Max^2-G, and singleton chain shift of /g/>[k], /k/>[k^h] by Dep-LG. Similarly, in my Ident analysis, the geminate chain shift is explained by the constraint conjunction Id[Voi&Dur]-G and the singleton chain shift by Id[Voi]-G&Max-

G. It would have been more satisfying if a single constraint or two very closely constraints could have been found that accounted for both the geminate and the singleton chain shifts.

A theoretical question whose implications I don't fully understand is the *VVO violation incurred by the transition t-unit of [V] to [k], [kʰ]. Examples of this violation can be seen in Figure 2 and Figure 3. In this analysis, deletion of the [k] and [kʰ] segments was blocked by undominated *Merge and high-ranking Max. However, I don't know if my *VVO is incorrectly formulated. If a language had *VVO outranking Max, this would result in either a complete lack of velar obstruents or at least partial vowel devoicing before velar obstruents. Therefore, constraints such as *VVO might be useful as tools to see if it is t-units or gestures that should be counted for violations in AP/OT. If a language exists with no voiced velar obstruents and also vowel devolving before voiceless velar obstruents, that might be evidence that it is t-units that are important.

One way in which the analysis might be improved is if aspiration were treated as a full segment permanently associated with other segments. This is not an entirely unreasonable assumption, as some authors such as Helgason (2002) have already suggested as such. If this were indeed the case, then Dep-LG might be replaced with Dep^2-G, which would render the Max/Dep analysis symmetrical. This would, however, also introduce a whole host of problems about the representation of aspiration in AP, and raise questions for Gafos's (2002) gestural landmarks. If aspiration is a segment, then it would appear that there would be no distinction that could be made between aspiration and /h/.

Another way in which the analysis might be improved is if preaspiration were treated the same as aspiration but in reverse. As this has been argued by many authors in the past, this is also not entirely unreasonable, despite certain phonetic studies which point to the contrary conclusion. If that were indeed the case, then only one of the constraint conjunctions, Id[Voi&Dur]-G would be necessary. This would, however, also require that geminates be a single segment, which would also introduce problems for my formulation of AP. It would become unclear what the proper way to show timing units on a score would be. This particular improvement also runs afoul of other observations that have been made about syllable patterns in Icelandic, which suggests that this might not be a useful path of inquiry.[14]

5 Conclusions

In this thesis, I have argued for a novel method of conducting historical analysis grounded in Articulatory Phonology and Optimality Theory. Specifically, I have argued that this is

[14] For those observations, see Árnason 2011 or any description of Icelandic from the last century.

a framework that has inherent explanatory power when it comes to historical phonology. As a proof of concept, I have presented an analysis of the development of the Old Norse oral stop subsystem into the Icelandic oral stop subsystem, and have shown how the use of gestures as units of analysis makes the process of describing language change clearer. In this way, this thesis has been an argument for the use of frameworks which incorporate phonetics into phonology.

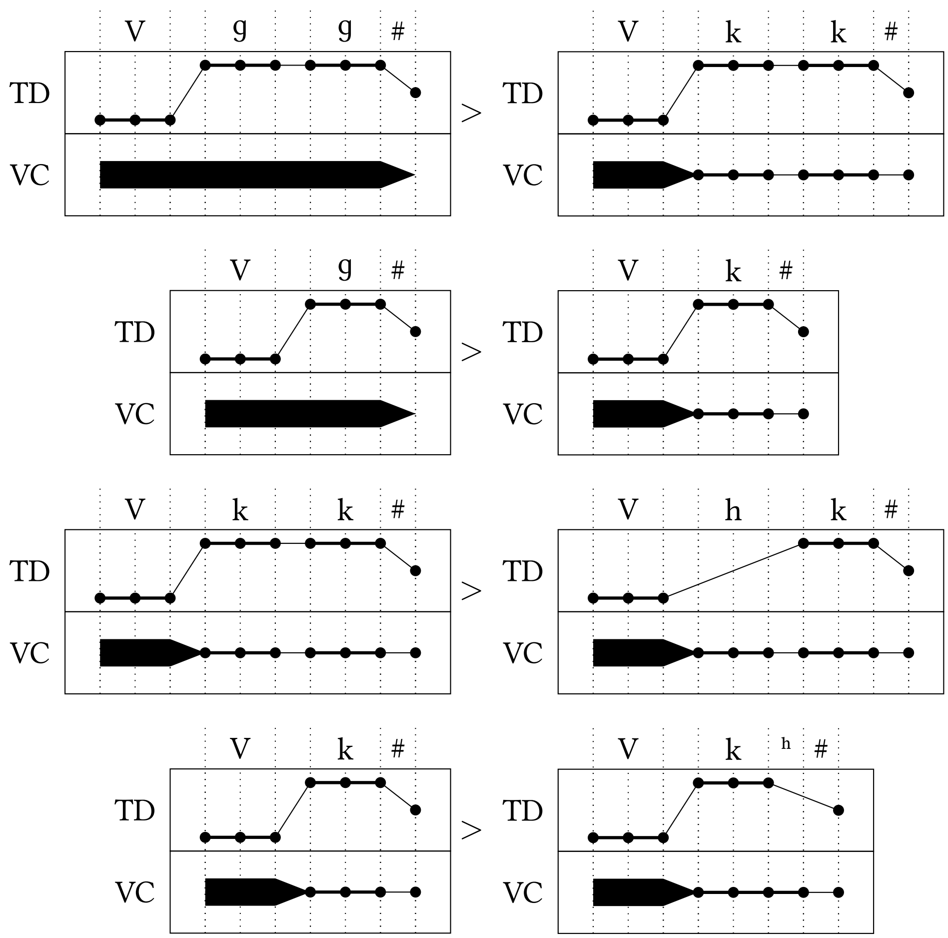
Through this process, I have endeavored to make clear the assumptions that I made; although this thesis does not specifically argue for those assumptions, I invite anyone interested in advocating for or against them to do so, as I believe that I have made no heinously bad assumptions and would like to believe I have only made ones that are sensible. In this way, this thesis has been a loose map of certain directions research into the underlying assumptions of AP/OT might go; more broadly, of directions research into theories which encode the phonetics-phonology connection might go. It is my hope that this thesis is useful to someone, for either, but preferably both, of these reasons.

Appendix A: A succinct presentation of scores

Included here are the scores for the velar oral stops, with Old Norse in the left column and Icelandic in the right. Not included are the scores for the alveolar and bilabial oral stops, as it is understood that they would look identical but for the change in the label of the constriction location.

This appendix makes it easy to compare the nature of the old subsystem with the new, in terms of AP gestural scores, and, as befits an appendix, does not contain critical information.

(34)



When the information is laid out as in (34), it is clear that, given the assumption that geminates are two segments, each shift consists of no more than one change per segment; this suggests the necessity of conjunction constraints, as it appears that multiple changes are not permissible when segments are concerned, but that single changes are. As I have said in §5, this is one way in which AP makes historical analysis simpler, for the representation itself suggests what the analysis should be.

Appendix B: Tables and Figures

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References

Alderete, John. 1997. Dissimilation as local conjunction. In Kiyomi Kusumoto, ed. *Proceedings of the North East Linguistics Society* 27. Amherst, MA: GLSA, University of Massachusetts. 17–31.

Árnason, Kristján. 1978. Palatalization in Modern Icelandic: A case for historicism in synchronic linguistics. *Lingua* 46:185–203.

Árnason, Kristján. 1980. *Quantity in historical phonology: Icelandic and related cases.* Cambridge: Cambridge University Press.

Árnason, Kristján. 2011. *The phonology of Icelandic and Faroese.* New York: Oxford University Press.

Bandle, Oscar, Kurt Braunmüller, and E. H. Jahr, eds. 2002. *Nordic languages: An international handbook of the history of the North Germanic languages.* Berlin: De Gruyter Mouton.

Benediktsson, Hreinn. 1959. The vowel system of Icelandic: A survey of its history. *The Word-Journal of the International Linguistic Association* 15:282–312.

Benediktsson, Hreinn. 1972. *The first grammatical treatise: Introduction, text, notes, translation, vocabulary, facsimiles.* Reykjavík: Institute of Nordic Linguistics.

Bradley, Travis G. 2002. Gestural timing and derived environment effects in Norwegian clusters. In Line Mikkelsen and Christopher Potts, eds. *WCCFL 21 Proceedings.* WCCFL. Cascadilla Press. 43–56.

Bradley, Travis G. 2007. Morphological derived-environment effects in gestural coordination: A case study of Norwegian clusters. *Lingua* 117:960–985.

Bradley, Travis G. 2014. Optimality Theory and Spanish phonology. *Language and Linguistics Compass* 8:65–88.

Browman, Catherine P. and Louis M. Goldstein. 1986. Towards an articulatory phonology. *Phonology* 3:219–252.

Browman, Catherine P. and Louis M. Goldstein. 1988. Some notes on syllable structure in Articulatory Phonology. *Phonetica* 45:140–155.

Browman, Catherine P. and Louis M. Goldstein. 1990. Tiers in Articulatory Phonology, with some implications for casual speech. In John Kingston and Mary E. Beckman, eds. *Papers in laboratory phonology I: Between the grammar and physics of speech.* Cambridge: Cambridge University Press. 341–376.

Browman, Catherine P. and Louis M. Goldstein. 1992. Articulatory Phonology: An overview. *Phonetica* 49:155–180.

Bybee, Joan. 2001. *Phonology and language use.* No. 94 in Cambridge Studies in Linguistics. New York: Cambridge University Press.

Campbell, Lyle. 2013. *Historical linguistics.* Cambridge, MA: The MIT Press. 3rd ed.

Chapman, Kenneth G. 1962. *Icelandic-Norwegian linguistic relationships.* Boston, MA: Scandanavian University Books.

Cho, Taehong. 1998. Intergestural overlap and timing in Korean palatalization: An Optimality Theoretic approach. *Japanese/Korean Linguistics* 8:261–276.

Cho, Young-mee Yu. 1995. Language change as a reranking of constraints. In Richard M. Hogg and Linda van Bergen, eds. *Historical linguistics: Germanic linguistics. Selected papers* 2. Amsterdam: John Benjamins Publishing Company. 45–62.

Chomsky, Noam. 1995. *The minimalist program.* Cambridge: Cambridge University Press.

Clements, George N. 1976/1980. *Vowel harmony in nonlinear generative phonology.* Bloomington, IN: Bloomington Indiana University Linguistics Club.

Davidson, Lisa. 2003. *The atoms of phonological representation: Gestures, coordination and perceptual features in consonant cluster phonotactics.* Doctoral dissertation. Johns Hopkins.

de Saussure, Ferdinand. 1912/1959. *Course in general linguistics.* Columbia University Press. Translated by Wade Baskin.

Einarsson, Stefán. 1945. *Icelandic: Grammar, texts, glossary.* Baltimore, MD: Johns Hopkins Press.

Eriksen, Anne and Jón Viðar Sigurðsson. 2015. *Negotiating pasts in the Nordic countries: Interdisciplinary studies in history and memory.* Lund: Nordic Academic Press.

Faarlund, Jan Terje. 2001. The notion of oblique subject and its status in the history of Icelandic. In Jan Terje Faarlund, ed. *Grammatical relations in change.* Amsterdam: John Benjamins Publishing Company. 99–135.

Faarlund, Jan Terje. 2002. *Old and Middle Scandanavian.* In König and van der Auwera (2002). 38–71.

Flemming, Edward S. 1995. *Auditory representations in phonology.* Doctoral dissertation. University of California Los Angeles.

Flemming, Edward S. 2004. Contrast and perceptual distinctiveness. In Bruce Hayes, Robert Kirchner, and Donca Steriade, eds. *Phonetically-based phonology.* New York: Cambridge University Press. 232–276.

Gafos, Adamantios I. 1999. *The articulatory basis of locality in phonology.* Outstanding dissertations in linguistics. New York: Garland Publishing Inc.

Gafos, Adamantios I. 2002. A grammar of gestural coordination. *Natural Language & Linguistic Theory* 20:269–337.

Goldsmith, John. 1976. *Autosegmental phonology.* Doctoral dissertation. MIT.

Gordon, Eric Valentine. 1927. *An introduction to Old Norse*. New York: Oxford University Press.

Hall, Nancy. 2003. *Gestures and segments: Vowel intrusion as overlap*. Doctoral dissertation. University of Massachusetts, Amherst.

Harbert, Wayne. 2007. *The Germanic languages*. Cambridge Language Surveys. New York: Cambridge University Press.

Haugen, Einar. 1950. First grammatical treatise. The earliest Germanic phonology. *Language* 26:4–64.

Haugen, Einar. 1958. The phonemics of modern Icelandic. *Language* 34:55–88.

Haugen, Einar. 1976. *The Scandanavian languages: An introduction to their history*. Cambridge, Massachusetts. Harvard University Press.

Haugen, Einar. 1982. *Scandanavian language structures: A comparative historical survey*. Tübingen, Germany: M. Niemeyer.

Helgason, Pétur. 2002. *Preaspiration in the Nordic languages: Synchronic and diachronic aspects*. Doctoral dissertation. Stockholm University.

Huffman, Franklin E. 1976. *The register problem in fifteen Mon-Khmer languages*. No. 1 in Oceanic Linguistics Special Publications. Honolulu, Hawaiʻi: University of Hawai'i Press.

Jespersen, Otto. 1949. *A Modern English grammar on historical principles. part I: Sounds and spellings*. Crows Nest, ID: George Allen & Unwin.

Karvonen, Daniel and Adam Sherman. 1997. Sympathy, opacity, and u-umlaut in Icelandic. In Motoko Katayama, Daniel Karvonen, and Rachel Walker, eds. *Phonology at Santa Cruz* 5. Santa Cruz, CA: University of Santa Cruz Press. 37–48.

Kawahara, Shigeto. 2006. A faithfulness ranking projected from a perceptibility scale: The case of [+voice] in Japanese. *Language* 82:536–574.

König, Ekkehard and Johan van der Auwera, eds. 2002. *The Germanic languages*. Routledge Language Family Descriptions. New York: Routledge.

Labrune, Laurence. 2012. *The phonology of Japanese*. Oxford: Oxford University Press.

Lass, Roger. 1994. *Old English: A historical linguistic companion*. Cambridge: Cambridge University Press.

Lewis, M. Paul, Gary F. Simons, and Charles D. Fennig, eds. 2015. *Ethnologue: Languages of the world*. Dallas, TX: SIL International. 18th ed. Online version: `http://www.ethnologue.com`.

Łubowicz, Anna. 2003. *Contrast preservation in phonological mappings*. Doctoral dissertation. University of Massachusetts, Amherst.

Malone, Kemp. 1923. *The phonology of Modern Icelandic.* No. 15 in Ottendorfer Memorial Series of Germanic Monographs. Lawrence, KS: The Collegiate Press.

Malone, Kemp. 1952. The phonemes of Modern Icelandic. In L. R. Lind, ed. *Studies in Honor of Albert Morey Sturtevant.* No. 29 in Humanistic Studies. Lawrence, KS: University of Kansas Press. 5–21.

McCarthy, John. 1981. A prosodic theory of nonconcatenative morphology. *Linguistic Inquiry* 3:373–418.

McCarthy, John and Alan Prince. 1995. Faithfulness and reduplicative identity. In Jill Beckman, Laura Walsh Dickey, and Suzanne Urbanczyk, eds. *Papers in Optimality Theory.* Amherst, MA: Graduate Linguistic Student Association.

Montreuil, Jean-Pierre. 2006. Contrast preservation theory and historical change. In Randall Gess and Deborah Arteaga, eds. *Historical Romance linguistics: Retrospective and perspectives.* Amsterdam: John Benjamins Publishing Company. 111–129.

Napoli, Donna Jo, Nathan Sanders, and Rebecca Wright. 2014. On the linguistic effects of articulatory ease, with a focus on sign languages. *Language* 90:424–456.

Nielsen, Hans Frede. 1989. *The Germanic languages: Origins and early dialectal interrelations.* Tuscaloosa, AL: University of Alabama Press.

Noske, Roland. 2012. The Grimm-Verner push chain and contrast preservation theory. In Bert Botma and Roland Noske, eds. *Phonological explorations. Empirical, theoretical and diachronic issues.* Berlin: De Gruyter. 63–86.

Ohala, John J. 1983. The origin of sound patterns in vocal tract constraints. In Peter F. MacNeilage, ed. *The production of speech.* New York: Springer. 189–216.

Padgett, Jaye. 2003. Contrast and post-velar fronting in Russian. *Natural Language & Linguistic Theory* 21:39–87.

Pater, Joe. 1999. Austronesian nasal substitution and other NC effects. In René Kager, Harry van der Hulst, and Wim Zonneveld, eds. *The prosody-morphology interface.* Cambridge: Cambridge University Press. 310–343.

Pater, Joe. 2001. Austronesian nasal substitution revisited. In Linda Lombardi, ed. *Segmental phonology in Optimality Theory: Constraints and representations.* Cambridge: Cambridge University Press. 159–182.

Prince, Alan and Paul Smolensky. 1993/2004. *Optimality Theory: Constraint interaction in generative grammar.* Hoboken, NJ: Wiley-Blackwell.

Proctor, Michael Ian. 2009. *Gestural characterization of a phonological class: The liquids.* Doctoral dissertation. Yale.

Þráisson, Höskuldur. 1978. On the phonology of Icelandic prespiration. *Nordic Journal of Linguistics* 1:3–54.

Þráisson, Höskuldur. 2002. *Icelandic*. In König and van der Auwera (2002). 142–189.

Reiss, Charles. 2003. Language change without constraint reranking. In D. Eric Holt, ed. *Optimality Theory and language change*. Berlin: Kluwer Academic Publishers. 143–168.

Sanders, Nathan. 2003. *Opacity and sound change in the Polish lexicon*. Doctoral dissertation. University of California, Santa Cruz.

Sandøy, Helge. 2002. *The typological development of the Nordic languages I: Phonology*. In volume 2 of Bandle et al. (2002). 1852–1886.

Schulte, Michael. 2002. *Phonological developments from Old Norse to Early Modern Nordic I: West Scandanavian*. In volume 2 of Bandle et al. (2002). 1081–1097.

Sigmundsson, Svavar. 2002. *Trends in the linguistic development since 1945: Icelandic*. In volume 2 of Bandle et al. (2002). 1832–1839.

Sigurðsson, Jón Viðar. 1995. The Icelandic aristocracy after the fall of the free state. *Scandinavian Journal of History* 20:153–166.

Sweet, Henry. 1895. *An Icelandic primer with grammar, notes, and glossary*. Oxford: Clarendon Press.

Trubetzkoy, Nikolai. 1876/1969. *Principles of phonology*. Los Angeles: University of California Press. Translated by Christiane A. M. Baltaxe.

Vaux, Bert and Bridget Samuels. 2005. Explaining vowel systems: Dispersion Theory vs natural selection. *The Linguistic Review* 32:573–599.

Westbury, John R. and Patricia A. Keating. 1986. On the naturalness of stop consonant voicing. *Journal of Linguistics* 22:145–166.